

Sweave User Manual

Friedrich Leisch

R Version 1.5.0

Contents

1	Introduction	2
2	Noweb files	2
3	Sweave files	3
3.1	A simple example	3
3.2	Sweave options	4
3.3	Using scalars in text	6
3.4	Code chunk reuse	7
3.5	Syntax definition	7
4	Tangling and weaving	7
	Sweave	9
4.1	The <code>RweaveLatex</code> driver	10
	<code>RweaveLatex</code>	10
4.2	The <code>Rtangle</code> driver	12
	<code>Rtangle</code>	12
A	Frequently Asked Questions	13

1 Introduction

Sweave provides a flexible framework for mixing text and S code for automatic document generation. A single source file contains both documentation text and S code, which are then *woven* into a final document containing

- the documentation text together with
- the S code and/or
- the output of the code (text, graphs)

by running the S code through an S engine¹ like R². This allows to re-generate a report if the input data change and documents the code to reproduce the analysis in the same file that also contains the report. The S code of the complete analysis is embedded into a L^AT_EX document³ using the noweb syntax (Ramsey, 1998). Hence, the full power of L^AT_EX (for high-quality typesetting) and S (for data analysis) can be used simultaneously. See Leisch (2002) and references therein for more general thoughts on dynamic report generation and pointers to other systems.

Many S users are also L^AT_EX users, hence no new software or syntax has to be learned. The Emacs text editor (Stallman, 1999) offers a perfect authoring environment for Sweave, especially for people which already use Emacs for writing L^AT_EX documents and interacting with an S engine. We have chosen to use noweb as basis for the Sweave system because

1. the syntax is extremely simple and hence easy to learn
2. the ESS noweb mode for Emacs already provides a perfect authoring environment (Rossini et al., 2001)

The importance of 2 should not be underestimated: A document format without convenient tools for authors will almost certainly be ignored by prospective users. However, it is not necessary to use Emacs. Sweave is a standalone system, the noweb source files for Sweave can be written using any text editor.

Sweave uses a modular concept using different drivers for the actual translations. Obviously different drivers are needed for different text markup languages (L^AT_EX, HTML, ...). Unfortunately we will also need different drivers for different S engines (R, S-Plus⁴), because we make extensive usage of `eval()`, connections, and the graphics devices, and the various S engines have some differences there. Currently there is only the driver `RWeaveLatex` which combines R and L^AT_EX.

2 Noweb files

Noweb (Ramsey, 1998) is a simple literate-programming tool which allows to combine program source code and the corresponding documentation into a single file. Different programs allow to extract documentation and/or source code. A noweb file is a simple text file which consists of a sequence of code and documentation segments, these segments are called *chunks*:

Documentation chunks start with a line that has an at sign (@) as first character, followed by a space or newline character. The rest of this line is a comment and ignored. Typically documentation chunks will contain text in a markup language like L^AT_EX.

Code chunks start with `<<name>>=` at the beginning of a line; again the rest of the line is a comment and ignored.

¹ See Becker et al. (1988) and Chambers (1998) for definitions of the S language, and Venables and Ripley (2000) for details on the term *S engine* and detailed descriptions of differences between various implementations of the S language.

²<http://www.R-project.org>

³<http://www.ctan.org/>

⁴<http://www.insightful.com>

The default for the first chunk is documentation.

In the simplest usage of noweb, the (optional) names of code chunks give the name of source code files, and the tool `notangle` can be used to extract the code chunk from the noweb file. Multiple code chunks can have the same name, the corresponding code chunks are concatenated when the source code is extracted. Noweb has some additional mechanisms to cross-reference code chunks (the `[[...]]` operator, etc.), Sweave does currently not use or support these features, hence they are not described here.

3 Sweave files

3.1 A simple example

Sweave source files are regular noweb files with some additional syntax that allows some additional control over the final output. Traditional noweb files have the extension `.nw`, which is also fine for Sweave files (and fully supported by the software). Additionally, Sweave currently recognizes files with extensions `.rnw`, `.Rnw`, `.snw` and `.Snw` to directly indicate a noweb file with Sweave extensions. We will use `.Snw` throughout this document.

A minimal Sweave file is shown in Figure 1, which contains two code chunks embedded in a simple \LaTeX document. Sweave translates this into the \LaTeX document shown in Figures 2 and 3. The first difference between the `example-1.Snw` and `example-1.tex` is that the \LaTeX style file `Sweave.sty` is automatically loaded, which provides environments for typesetting S input and output (the \LaTeX environments `Sinput` and `Soutput`). Otherwise, the documentation chunks are copied without any modification from `example-1.Snw` to `example-1.tex`.

```
\documentclass[a4paper]{article}

\title{Sweave Example 1}
\author{Friedrich Leisch}

\begin{document}

\maketitle

In this example we embed parts of the examples from the
\texttt{kruskal.test} help page into a \text{\LaTeX{}} document:

<<>>=
data(airquality)
library(ctest)
kruskal.test(Ozone ~ Month, data = airquality)
@
which shows that the location parameter of the Ozone
distribution varies significantly from month to month. Finally we
include a boxplot of the data:

\begin{center}
<<fig=TRUE,echo=FALSE>>=
boxplot(Ozone ~ Month, data = airquality)
@
\end{center}

\end{document}
```

Figure 1: A minimal Sweave file: `example-1.Snw`.

The real work of Sweave is done on the code chunks: The first code chunk has no name, hence

the default behavior of Sweave is used, which transfers both the S commands and their respective output to the \LaTeX file, embedded in `Sinput` and `Soutput` environments, respectively.

The second code chunk shows one of the Sweave extension to the noweb syntax: Code chunk names can be used to pass options to Sweave which control the final output.

- The chunk is marked as a figure chunk (`fig=TRUE`) such that Sweave creates EPS and PDF files corresponding to the plot created by the commands in the chunk. Furthermore, a `\includegraphics{example-1-002}` statement is inserted into the \LaTeX file (details on the choice of filenames for figures follow later in this manual).
- Option `echo=FALSE` indicates that the S input should not be included in the final document (no `Sinput` environment).

```
\documentclass[a4paper]{article}

\title{Sweave Example 1}
\author{Friedrich Leisch}

\usepackage{/home/Leisch/work/R/build-devel/library/tools/Sweave/Sweave}
\begin{document}

\maketitle

In this example we embed parts of the examples from the
\texttt{kruskal.test} help page into a \LaTeX{} document:

\begin{Sinput}
R> data(airquality)
R> library(ctest)
R> kruskal.test(Ozone ~ Month, data = airquality)
\end{Sinput}
\begin{Soutput}
    Kruskal-Wallis rank sum test

data:  Ozone by Month
Kruskal-Wallis chi-squared = 29.2666, df = 4, p-value = 6.901e-06
\end{Soutput}
which shows that the location parameter of the Ozone
distribution varies significantly from month to month. Finally we
include a boxplot of the data:

\begin{center}
\includegraphics{example-1-002}
\end{center}

\end{document}
```

Figure 2: The output of `Sweave("example-1.Snw")` is the file `example-1.tex`.

3.2 Sweave options

Options control how code chunks and their output (text, figures) are transferred from the `.Snw` file to the `.tex` file. All options have the form `key=value`, where `value` can be a number, string or logical value. Several options can be specified at once (seperated by commas), all options must take a value (which must not contain a comma or equal sign). Logical options can take the values `true`, `false`, `t`, `f` and the respective uppercase versions.

Sweave Example 1

Friedrich Leisch

April 9, 2002

In this example we embed parts of the examples from the `kruskal.test` help page into a \LaTeX document:

```
R> data(airquality)
R> library(ctest)
R> kruskal.test(Ozone ~ Month, data = airquality)
```

Kruskal-Wallis rank sum test

data: Ozone by Month

Kruskal-Wallis chi-squared = 29.2666, df = 4, p-value = 6.901e-06

which shows that the location parameter of the Ozone distribution varies significantly from month to month. Finally we include a boxplot of the data:

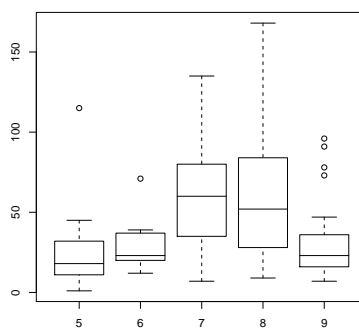


Figure 3: The final document is created by running `latex` on `example-1.tex`.

In the `.Snw` file options can be specified either

1. inside the angle brackets at the beginning of a code chunk, modifying the behaviour *only for this chunk*, or
2. anywhere in a documentation chunk using the command

```
\SweaveOpts{opt1=value1, opt2=value2, ..., optN=valueN}
```

which modifies the defaults for the rest of the document, i.e., *all code chunks after the statement*. Hence, an `\SweaveOpts` statement in the preamble of the document sets defaults for all code chunks.

Which options are supported depends on the driver in use. All drivers should at least support the following options (all options appear together with their default value, if any):

engine=S: a character string describing which S engines are able to handle the respective code chunks. Possible values are, e.g., `S`, `R`, `S3` or `S4`. Each driver only processes compatible code chunks and ignores the rest.

split=FALSE: a logical value. If `TRUE`, then the output is distributed over several files, if `FALSE` all output is written to a single file. Details depend on the driver.

label: a text label for the code chunk, which is used for filename creation when `split=TRUE`. If the label is of form `label.engine`, then the extension is removed before further usage (e.g., label `hello.S` is reduced to `hello`).

The first (and only the first) option in a code chunk name can be optionally without a name, then it is taken to be a label. I.e., starting a code chunk with

```
<<hello.S, split=FALSE>>
```

is the same as

```
<<split=FALSE, label=hello.S>>
```

but

```
<<split=FALSE, hello.S>>
```

gives a syntax error. Having an unnamed first argument for labels is needed for noweb compatibility. If only `\SweaveOpts` is used for setting options, then Sweave files can be written to be fully compatible with noweb (as only filenames appear in code chunk names).

3.3 Using scalars in text

There is limited support for using the values of S objects in text chunks. Any occurrence of `\Sexpr{expr}` is replaced by the string resulting from coercing the value of the expression `expr` to a character vector; only the first element of this vector is used. E.g., `\Sexpr{sqrt(9)}` will be replaced by the string `'3'` (without any quotes).

The expression is evaluated in the same environment as the code chunks, hence one can access all objects defined in the code chunks which have appeared before the expression and were not ignored. The expression may contain any valid S code, only curly brackets are not allowed. This is not really a limitation, because more complicated computations can be easily done in a hidden code chunk and the result then be used inside a `\Sexpr`.

3.4 Code chunk reuse

Named code chunks can be reused in other code chunks following later in the document. Consider the simple example

```
<<a>>=
x <- 10
@

<<b>>=
x + y
@

<<c>>=
<<a>>
y <- 20
<<b>>
@
```

which is equivalent to defining the last code chunk as

```
<<c>>=
x <- 10
y <- 20
x + y
@
```

The chunk reference operator `<<>>` takes only the name of the chunk as argument, without any additional Sweave options.

3.5 Syntax definition

So far we have only talked about Sweave files using `noweb` syntax (which is the default). However, Sweave allows the user to redefine the syntax marking documentation and code chunks, using scalars in text or reuse code chunks.

Figure 4 shows the example from Figure 1 using the `SweaveSyntaxLatex` definition. Code chunks are now enclosed in `Scode` environments, code chunk reuse is performed using `\Scoderef{chunkname}`. All other operators are the same as in the `noweb`-style syntax.

Which syntax is used for a document is determined by the extension of the input file, files with extension `.Rtex` or `.Stex` are assumed to follow the \LaTeX -style syntax. Alternatively the syntax can be changed at any point within the document using the commands

```
\SweaveSyntax{SweaveSyntaxLatex}
```

or

```
\SweaveSyntax{SweaveSyntaxNoweb}
```

at the beginning of a line within a documentation chunk. Syntax definitions are simply lists of regular expression for several Sweave commands, see the two default definitions mentioned above for examples (more detailed intructions will follow once the API has stabilized).

4 Tangling and weaving

The user frontends of the Sweave system are the two S functions `Stangle()` and `Sweave()`. Both (together with all available drivers for R) are contained in the base R package `tools` for R version 1.5.0 and later (<http://www.R-project.org>). `Stangle` can be used to extract only the code

```

\documentclass[a4paper]{article}

\title{Sweave Example 1}
\author{Friedrich Leisch}

\begin{document}

\maketitle

In this example we embed parts of the examples from the
\texttt{kruskal.test} help page into a \LaTeX{} document:

\begin{Scode}
data(airquality)
library(ctest)
kruskal.test(Ozone ~ Month, data = airquality)
\end{Scode}
which shows that the location parameter of the Ozone
distribution varies significantly from month to month. Finally we
include a boxplot of the data:

\begin{center}
\begin{Scode}{fig=TRUE,echo=FALSE}
boxplot(Ozone ~ Month, data = airquality)
\end{Scode}
\end{center}

\end{document}

```

Figure 4: An Sweave file using L^AT_EX syntax: `example-1.Stex`.

chunks from an `.Snw` file and write to one or several files. `Sweave()` runs the code chunks through an S engine and replaces them with the respective input and/or output. `Stangle` is actually just a wrapper function for `Sweave`, which uses a tangling instead of a weaving driver by default.

Sweave

Automatic Generation of Reports

Description

`Sweave` provides a flexible framework for mixing text and S code for automatic report generation. The basic idea is to replace the S code with its output, such that the final document only contains the text and the output of the statistical analysis.

Usage

```
Sweave(file, driver=RWeaveLatex(), syntax=getOption("SweaveSyntax"), ...)
Stangle(file, driver=RTangle(), syntax=getOption("SweaveSyntax"), ...)
```

Arguments

<code>file</code>	Name of Sweave source file.
<code>driver</code>	The actual workhorse, see details below.
<code>syntax</code>	An object of class <code>SweaveSyntax</code> or a character string with its name. The default installation provides <code>SweaveSyntaxNoweb</code> and <code>SweaveSyntaxLatex</code> .
<code>...</code>	Further arguments passed to the driver's setup function.

Details

Automatic generation of reports by mixing word processing markup (like latex) and S code. The S code gets replaced by its output (text or graphs) in the final markup file. This allows to re-generate a report if the input data change and documents the code to reproduce the analysis in the same file that also produces the report.

`Sweave` combines the documentation and code chunks together (or their output) into a single document. `Stangle` extracts only the code from the Sweave file creating a valid S source file (that can be run using `source`). Code inside `\Sexpr{}` statements is ignored by `Stangle`.

`Stangle` is just a frontend to `Sweave` using a simple driver by default, which discards the documentation and concatenates all code chunks the current S engine understands.

Hook Functions

Before each code chunk is evaluated, a number of hook functions can be executed. If `getOption("SweaveHooks")` is set, it is taken to be a collection of hook functions. For each logical option of a code chunk (`echo`, `print`, ...) a hook can be specified, which is executed if and only if the respective option is `TRUE`. Hooks must be named elements of the list returned by `getOption("SweaveHooks")` and be functions taking no arguments. E.g., if option `"SweaveHooks"` is defined as `list(fig = foo)`, and `foo` is a function, then it would be executed before the code in each figure chunk. This is especially useful to set defaults for the graphical parameters in a series of figure chunks.

Note that the user is free to define new Sweave options and associate arbitrary hooks with them. E.g., one could define a hook function for option `clean` that removes all objects in the global environment. Then all code chunks with `clean=TRUE` would start operating on an empty workspace.

Syntax Definition

Sweave allows a very flexible syntax framework for marking documentation and text chunks. The default is a noweb-style syntax, as alternative a latex-style syntax can be used. See the user manual for details.

Author(s)

Friedrich Leisch

References

Friedrich Leisch: Sweave User Manual, 2002
<http://www.ci.tuwien.ac.at/~leisch/Sweave>

Friedrich Leisch: Dynamic generation of statistical reports using literate data analysis. Report 69, SFB “Adaptive Information Systems and Modelling in Economics and Management Science”, March 2002.

See Also

RweaveLatex, Rtriangle

Examples

```
testfile <- file.path(.path.package("tools"),
                      "Sweave", "Sweave-test-1.Rnw")

## create a LaTeX file
Sweave(testfile)

## create an S source file from the code chunks
Stangle(testfile)
## which can be simply sourced
source("Sweave-test-1.R")
```

4.1 The RweaveLatex driver

This driver transforms .Snw files with L^AT_EX documentation chunks and R code chunks to proper L^AT_EX files (for typesetting both with standard latex or pdf_latex).

RweaveLatex

R/LaTeX Driver for Sweave

Description

A driver for Sweave that translates R code chunks in LaTeX files.

Usage

```
RweaveLatex()
RweaveLatexSetup(file, syntax, output=NULL, quiet=FALSE, debug=FALSE,
                  echo=TRUE, eval = TRUE, split=FALSE, stylepath=TRUE,
                  pdf=TRUE, eps=TRUE)
```

Arguments

<code>file</code>	Name of Sweave source file.
<code>syntax</code>	An object of class <code>SweaveSyntax</code> .
<code>output</code>	Name of output file, default is to remove extension <code>‘.nw’</code> , <code>‘.Rnw’</code> or <code>‘.Snw’</code> and to add extension <code>‘.tex’</code> . Any directory names in <code>file</code> are also removed such that the output is created in the current working directory.
<code>quiet</code>	If <code>TRUE</code> all progress messages are suppressed.
<code>debug</code>	If <code>TRUE</code> , input and output of all code chunks is copied to the console.
<code>stylepath</code>	If <code>TRUE</code> , a hard path to the file <code>‘Sweave.sty’</code> installed with this package is set, if <code>FALSE</code> , only <code>\usepackage{Sweave}</code> is written. The hard path makes the TeX file less portable, but avoids the problem of installing the current version of <code>‘Sweave.sty’</code> to some place in your TeX input path. The argument is ignored if a <code>\usepackage{Sweave}</code> is already present in the Sweave source file.
<code>echo</code>	set default for option <code>echo</code> , see details below.
<code>eval</code>	set default for option <code>eval</code> , see details below.
<code>split</code>	set default for option <code>split</code> , see details below.
<code>pdf</code>	set default for option <code>pdf</code> , see details below.
<code>eps</code>	set default for option <code>eps</code> , see details below.

Supported Options

Author(s)

Friedrich Leisch

References

Friedrich Leisch: Sweave User Manual, 2002
<http://www.ci.tuwien.ac.at/~leisch/Sweave>

See Also

Sweave, Rtriangle

If `split` is set to `TRUE`, then all text corresponding to code chunks (the `Sinput` and `Soutput` environments) is written to separate files. The filenames are of form `prefix.string-label.tex`, if several code chunks have the same label, their outputs are concatenated. If a code chunk has no label, then the number of the chunk is used instead. The same naming scheme applies to figures.

The driver automatically inserts a `\usepackage{.../Sweave.sty}` command as last line before the `\begin{document}` statement of the final \LaTeX file if no `\usepackage{Sweave}` is found in the Sweave source file. This style file defines the environments `Sinput` and `Soutput` for typesetting code chunks. It also sets the default \LaTeX figure width (which is independent of the size of the generated EPS and PDF files). The current default is

```
\setkeys{Gin}{width=0.8\textwidth}
```

if you want to use another width for the figures that are automatically generated and included by Sweave, simply add a line similar to the one above *after* `\begin{document}`. Note that a new graphics device is opened for each figure chunk (option `fig=TRUE`), hence all graphical parameters of the `par()` command must be set in each single figure chunk and are forgotten after the respective chunk (because the device is closed when leaving the chunk).

Attention: One thing that gets easily confused are the width/height parameters of the R graphics devices and the corresponding arguments to the \LaTeX `\includegraphics` command. The Sweave options `width` and `height` are passed to the R graphics devices, and hence affect the default size of the produced EPS and PDF files. They do not affect the size of figures in the document, by default they will always be 80% of the current text width. Use `\setkeys{Gin}` to modify figure sizes or use explicit `\includegraphics` commands in combination with Sweave option `include=FALSE`.

We need ex-
ample code
for that

4.2 The Rtangle driver

This driver can be used to extract S and R code chunks from a `.Snw` file. Code chunks can either be written to one large file or separate files (one for each label). The options `split`, `prefix`, `prefix.string` and `engine` have the same defaults and interpretation as for the `RweaveLatex` driver. Use the standard noweb command line tool `notangle` if other chunks than R or S code should be extracted.

Rtangle	<i>R Driver for Stangle</i>
---------	-----------------------------

Description

A driver for `Stangle` that extracts R code chunks.

Usage

```
Rtangle()
RtangleSetup(file, syntax, output=NULL, annotate=TRUE, split=FALSE,
             prefix=TRUE, quiet=FALSE)
```

Arguments

<code>file</code>	Name of Sweave source file.
<code>syntax</code>	An object of class <code>SweaveSyntax</code> .
<code>output</code>	Name of output file, default is to remove extension <code>'nw'</code> , <code>'Rnw'</code> or <code>'Snw'</code> and to add extension <code>'R'</code> . Any directory names in <code>file</code> are also removed such that the output is created in the current working directory.
<code>annotate</code>	By default, code chunks are separated by comment lines specifying the names and numbers of the code chunks. If <code>FALSE</code> , only the code chunks without any decorating comments are extracted.
<code>split</code>	Split output in single files per code chunk?
<code>prefix</code>	If <code>split=TRUE</code> , prefix the chunk labels by the basename of the input file to get output file names?
<code>quiet</code>	If <code>TRUE</code> all progress messages are suppressed.

Author(s)

Friedrich Leisch

References

Friedrich Leisch: Sweave User Manual, 2002
<http://www.ci.tuwien.ac.at/~leisch/Sweave>

See Also

Sweave, RweaveLatex

Acknowledgements

The author wants to thank Vince Carey, Robert Gentleman, Kurt Hornik and Dietrich Trenkler for providing valuable comments and ideas and testing early development versions of the software.

A Frequently Asked Questions

- **Where can I find the manual and other information on Sweave?**

The newest version of the Sweave manual can always be found at the URL

<http://www.ci.tuwien.ac.at/~leisch/Sweave>

where you also find additional example files.

- **How can I get Emacs to automatically recognize files in Sweave format?**

Include something like the following in your `.emacs` file:

```
(defun Rnw-mode ()
  (noweb-mode)
  (if (fboundp 'R-mode)
      (setq noweb-default-code-mode 'R-mode)))
(add-to-list 'auto-mode-alist '("\\.Rnw\\'" . Rnw-mode))
(add-to-list 'auto-mode-alist '("\\.Snw\\'" . Rnw-mode))
```

- **Can I run Sweave directly from a shell?**

E.g., for writing makefiles it can be useful to run Sweave directly from a shell rather than manually start R and then run Sweave. This can easily be done using a simple shell script along the lines of

```
#!/bin/sh
echo "library(tools); Sweave(\"$1\")" | R --no-save --no-restore
```

- **Why does \LaTeX not find my EPS and PDF graphic files when the filename contains a dot?**

Sweave uses the standard \LaTeX package `graphicx` to handle graphic files, which automatically uses EPS files for standard \LaTeX and PDF files for \pdfLaTeX , if the name of the input file has no extension, i.e., contains no dots. Hence, you may run into trouble with graphics handling if the name of your Sweave file contains extra dots: `'foo.Rnw'` is OK, while `'foo.bar.Rnw'` is not.

- **Why does Sweave by default create both EPS and PDF graphic files?**

The \LaTeX package `graphicx` needs EPS files for plain \LaTeX , but PDF files for \pdfLaTeX (the latter can also handle PNG and JPEG files). Sweave automatically creates graphics in EPS and PDF format, such that the user can freely run `latex` or `pdflatex` on the final document as needed.

- **Why do R lattice graphics not work?**

The commands in package `lattice` have different behavior than the standard plot commands in the `base` package: lattice commands return an object of class `"trellis"`, the actual plotting is performed by the `print` method for the class. Encapsulating calls to lattice functions in `print()` statements should do the trick, e.g.:

```
<<fig=TRUE>>=  
library(lattice)  
print(bwplot(1:10))  
@
```

should work. Future versions of Sweave may have more automated means to deal with trellis graphics.

References

- Richard A. Becker, John M. Chambers, and Allan R. Wilks. *The New S Language*. Chapman & Hall, London, UK, 1988.
- John M. Chambers. *Programming with data: A guide to the S language*. Springer Verlag, Berlin, Germany, 1998.
- Friedrich Leisch. Sweave: Dynamic generation of statistical reports using literate data analysis. Report 69, SFB ‘Adaptive Information Systems and Modelling in Economics and Management Science’, March 2002. URL <http://www.ci.tuwien.ac.at/~leisch/Sweave>.
- R Development Core Team. *R: A language and environment for statistical computing*, 2001. URL <http://www.R-project.org>. version 1.4.0.
- Norman Ramsey. *Noweb man page*. University of Virginia, USA, 1998. URL <http://www.cs.virginia.edu/~nr/noweb>. version 2.9a.
- Anthony J. Rossini, Richard M. Heiberger, Kurt Hornik, and Martin Maechler. *ESS: Emacs Speaks Statistics*, 2002. URL <http://ess.stat.wisc.edu>. version 5.1.19.
- Anthony J. Rossini, Martin Mächler, Kurt Hornik, Richard M. Heiberger, and Rodney Sparapani. Emacs speaks statistics: A universal interface for statistical analysis. Report 164, Department of Biostatistics, University of Washington, 2001. URL <http://software.biostat.washington.edu/statsoft/ess/ess-techrep.pdf>.
- Richard M. Stallman. *The Emacs Editor*. Free Software Foundation, Boston, MA, USA, 1999. URL <http://www.gnu.org>. version 20.7.
- William N. Venables and Brian D. Ripley. *S Programming*. Springer, 2000.